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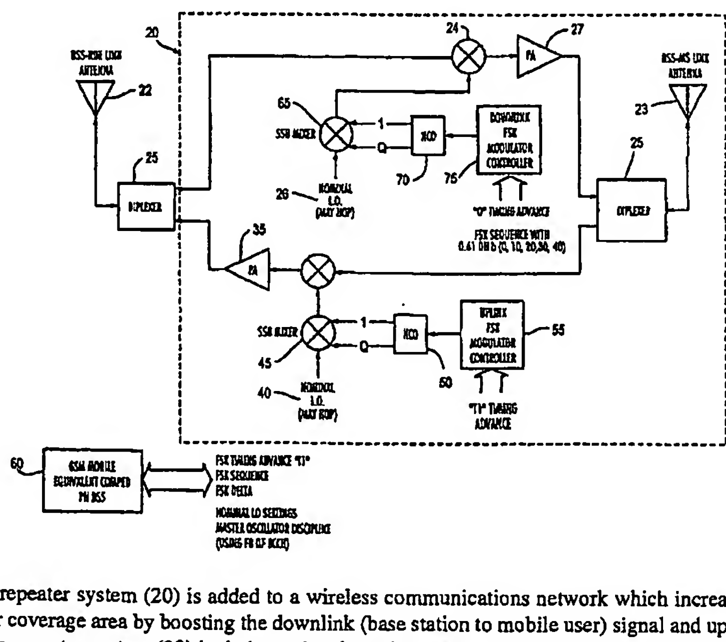
(54) Title: RF BASE STATION DATA REPEATER



(57) Abstract: A data repeater system (20) is added to a wireless communications network which increases user data rates at the periphery of the cellular coverage area by boosting the downlink (base station to mobile user) signal and uplink (mobile user to base station) signal. The data repeater system (20) includes a signal tagging means (61) which adds a unique electronic signature to the repeated signal such that position determination errors due to a non-line of sight propagation path can be corrected. The repeated signal is received and processed with a location measurement unit to determine the time of arrival and to extract the signal tag of the repeated signal. The time of arrival measurement and recovered signal tag are then processed at a mobile location center to determine the true position of the transmitter.

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— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

RF Base Station Data Repeater

Field of the Invention

This invention relates to RF data repeaters and more particularly, to the use of an RF repeater to enhance signal to noise and interference ratios with an electronic signature added to the repeated signal to eliminate location measurement errors.

Background of the Invention

Wireless data services are used for remote access of e-mail, internet, company information and others. In order to attract new and existing subscribers to data services, operators need to support perceived data rates of 64 kbps or greater. As wireless data services, such as GPRS and EDGE, are deployed, users will find that their realized data rate will decrease by a significant percentage when moved from locations near cell base station sites toward the cell edges. Typically, less than 20% of a cell area is estimated to be capable of the peak data rate in a coverage-limited deployment.

Wireless networks are currently being enhanced to provide position measurement capability. These methods provide the network with an estimate of the location of a mobile unit, such as for emergency 911 (E911) mobile phone service. Location Measurement Units (LMU) are typically inserted at the base station with time of arrival (TOA) signal processing means to estimate the distance from the mobile unit to the LMU, assuming straight line radio propagation.

RF repeaters are used to boost the mobile transmitted signals at the periphery of the coverage area. However, since the radio path taken through such a repeater may not be a direct path, the distance measured by the LMU does not correspond to the true straight-line distance from the LMU to the transmitting mobile unit. This results in significant location measurement errors for the repeated mobile signals.

One current method for solving the erroneous E911 LMU distance calculation problem is to co-locate an LMU next to each RF repeater along with a means for communicating the distance measurement information back to the network based mobile location center. This method is inefficient in at least two ways: first, it requires an LMU at every repeater site which adds to costs and makes each repeater site bulkier;

and second, a separate data link or additional data bits are needed to transmit the distance information to the base station.

Accordingly, there is a need for RF repeaters with the ability to enhance signal to noise and interference ratios over selected areas within the cell site, in particular to enable high data rate transmissions required by the wireless data systems.

Accordingly, there is a need for RF repeaters with the ability to tag signals passing through the repeater with unique electronic signatures so that the true locations of the transmitting mobile units can be identified.

Summary of the Invention

The invention provides in one aspect a data repeater which consist of two antenna functions, receive and transmit, per direction. In the downlink or forward direction (base station to mobile unit), the receive antenna function receives the base station transmitted signal and the transmit antenna function retransmits the downlink signal towards the mobile unit. In the uplink or reverse direction (mobile unit to base station), the receive antenna function receives the mobile unit transmitted signal and the transmit function retransmits the uplink signal towards the base station.

In one embodiment, one diplexed (combined transmit and receive with different frequencies) antenna is pointed in the direction of the desired base station and another diplexed antenna is pointed toward the desired location of increased mobile data service. The antennas are connected to an RF processing module which isolates the downlink and uplink signals, filters specific frequency bands, provides low noise amplification and transmitter power amplification circuitry, and circuitry for tagging the uplink signals.

In this embodiment, the data repeater consists of a diplexed antenna which is tuned to a predetermined uplink frequency band. The uplink signal, once received by the receiving antenna is routed to a diplexer (to separate it from the transmitted downlink signal) and further routed to uplink signal tagging equipment which introduces a unique electronic signature to the uplink signal to identify which data repeater is being used. This signal tagging may be performed by amplitude or phase modulation of the received uplink signal with an additional non-interfering direct

sequence spread spectrum signal. The modulated uplink signal is then routed to the output diplexer and transmitted to the base station with a diplexed antenna.

In another embodiment, the data repeater can introduce signal tagging on both the downlink and uplink signals through the repeater. The signal tagging may be performed by amplitude or phase modulation of the received downlink and uplink signals with additional non interfering direct sequence spread spectrum signals.

In existing and proposed wireless networks, the base stations include a Location Measurement Unit (LMU) to provide a mobile unit position determination capability. The LMU incorporates a time of arrival (TOA) receiver to measure the propagation time delay between the mobile unit and LMU and converts this time delay measurement to a distance measurement, assuming straight line propagation. The addition of data repeaters to the network will introduce errors in the position determination because the assumption of straight line propagation is no longer valid.

In the preferred embodiment, the unique uplink signal tag introduced by the data repeater is detected by additional circuitry in the LMU. A pseudonoise (PN) code correlator in the LMU detects the uplink signal tag and reports the repeater tag ID to the Mobile Location Center (MLC). The MLC determines the true position of the mobile unit from the TOA receiver measurements, the reported repeater tag ID information, and a database which includes geographical coordinates of the identified repeater.

Accordingly, one of the objects of the invention is to boost the signal levels over the desired areas to support higher data rates without the need to deploy a new base station.

It is the further object of the invention to tag the uplink signals passing through the repeater with unique electronic signatures so that the true locations of the transmitting mobile units can be identified.

Another object of the invention is to tag the downlink signals passing through the repeater with unique electronic signatures so that true locations of the transmitting base stations can be identified.

Other and further objects and advantages of the present invention will be further understood and appreciated by those skilled in the art by reference to the following specification, claims and drawings.

Brief Description of the Drawings

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate preferred embodiments of the invention, and together with the description, serve to explain the principles of the invention. Similar reference characters denote corresponding features consistently throughout the drawings..

Figure 1 is an illustration of a wireless communications cell site with additional high throughput coverage area provided by a data repeater.

Figure 2 shows an overview structure of a mobile unit position determination system according to the present invention.

Figure 3 shows a conceptual block diagram of a RF repeater with uplink signal tagging according to the present invention.

Figure 4 shows a conceptual block diagram of a RF repeater with uplink and downlink signal tagging according to the present invention.

Figure 5 shows a conceptual block diagram of a location measurement unit with circuitry to detect tagged signals according to the present invention.

Figure 6 shows the interaction between the location measurement unit and the mobile location center according to the present invention.

Detailed Description

Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals indicate like elements throughout the several views.

The present invention provides RF repeaters with the ability to enhance signal to noise and interference ratios over selected areas within the cell site, in particular to enable high data rate transmissions required by the wireless data systems. Additionally, it provides RF repeaters with the ability to tag signals passing through the repeater with unique electronic signatures so that the true locations of the transmitting mobile units can be identified.

Figure 1 is an illustration of a wireless communications cell site with additional high throughput coverage area provided by a data repeater. A base station 10 has a defined coverage area or cell site 11. Typically, selected areas within the cell site 11 could benefit from data rate enhancement. A repeater 20 or a plurality of repeaters are

usually strategically added within the cell site to enhance signal to noise and interference ratios in these particular areas of the coverage. However, since the radio path taken through such a repeater 20 may not be a direct-straight path, the distance measured by the LMU 12 does not correspond to the true straight-line distance from the LMU to the transmitting mobile unit. This results in significant location measurement errors for the repeated mobile signals.

Figure 2 shows an overview structure of a mobile unit position determination system (MUPDS) according to the present invention. The MUPDS comprises a mobile location center (MLC) 1, base stations 10, LMUs 12 and repeaters 20. The MLC determines the location of each mobile user with the user location information provided by the LMUs 12 as shown in Figures 5 and 6.

Figure 3 shows a conceptual block diagram of a RF repeater with uplink signal tagging according to the present invention. In Figure 3, the RF repeater comprises one diplexed (combined transmit and receive with different frequencies) antenna 22 which is pointed in the direction of the desired base station and another diplexed antenna 23 which is pointed toward the desired location of increased mobile data service. The antennas 22 & 23 are connected to an RF processing module 25 which isolates the downlink and uplink signals and filters specific frequency bands through the filter/diplexer 26a & 26b, provides low noise amplification and transmitter power amplification circuitry 27, modulation circuitry 28a & 28b, and circuitry for tagging the uplink signals 29a & 29b.

In this embodiment, the data repeater 20 consists of a diplexed antenna 23 which is tuned to a predetermined uplink frequency band. The uplink signal, once received by the receiving antenna is routed to a filter/diplexer 26b (to separate it from the transmitted downlink signal) and further routed to uplink signal tagging circuitry 29b which introduces a unique electronic signature to the uplink signal to identify which data repeater is being used. This signal tagging may be performed by amplitude or phase modulation 28b of the received uplink signal with an additional non-interfering direct sequence spread spectrum signal. The modulated uplink signal is then routed to the output diplexer 26a and transmitted to the base station with a diplexed antenna 22. Amplification of the signal can be achieved with the introduction of amplifiers 27 strategically located on the signal route as seen in Figure 3.

In another embodiment, the data repeater can introduce signal tagging on both the downlink and uplink signals through the repeater. The signal tagging may be performed by amplitude or phase modulation of the received downlink and uplink signals with additional non interfering direct sequence spread spectrum signals as shown in Figure 4. In this embodiment, the data repeater 20 consists of a diplexed antenna 23 which is tuned to a predetermined uplink frequency band. The uplink signal, once received by the receiving antenna is routed to a filter/diplexer 26b (to separate it from the transmitted downlink signal) and further routed to uplink signal tagging circuitry 29b which introduces a unique electronic signature to the uplink signal to identify which data repeater is being used. This signal tagging may be performed by amplitude or phase modulation 28b of the received uplink signal with an additional non-interfering direct sequence spread spectrum signal. The modulated uplink signal is then routed to the output diplexer 26a and transmitted to the base station with a diplexed antenna 22. Additionally, the data repeater 20 consists of a diplexed antenna 23 which is tuned to a predetermined downlink frequency band. The downlink signal, once received by the diplexed antenna 22 is routed to a filter/diplexer 26a (to separate it from the transmitted downlink signal) and further routed to the downlink signal tagging circuitry 29a which introduces a unique electronic signature to the downlink signal for unique identification. This signal tagging may be performed by amplitude or phase modulation 28a of the transmitted downlink signal with an additional non-interfering direct sequence spread spectrum signal. The modulated downlink signal is then routed to the output diplexer 26b and transmitted to a repeater or directly to a user with a diplexed antenna 23. Amplification of the signals can be achieved with the introduction of amplifiers 27 strategically located on the signal route as seen in Figure 4.

Figure 5 shows a conceptual block diagram of a location measurement unit (LMU) 12 with circuitry to detect tagged signals according to the present invention. In existing and proposed wireless networks, the base stations include a LMU 12 to provide a mobile unit position determination capability. The LMU 12 comprises a diplexed antenna 31, a filter/diplexer 32 , amplifiers 33, a mixer 37, IF chain 34 and I/Q demodulator 35. This portion of the LMU implementation is disclosed for illustrative purposes only. Other implementations of this portion of the LMU will be understood

by those skilled in the art. In the present invention, the LMU additionally incorporates a time of arrival (TOA) receiver 36 to measure the propagation time delay between the mobile unit and LMU, and subsequently, this time delay measurement may be converted to a distance measurement, assuming straight line propagation. However, with the addition of data repeaters to the network, errors in the position determination will be introduced because the assumption of straight line propagation is no longer valid. Hence, unique signal tags are introduced by the PN sequence generators 29 a & 29b as shown in Figures 3 and 4. These unique signal tags are detected by the pseudonoise (PN) code correlator 38 in the LMU which detects the signal tags and reports the repeater tag ID to the MLC 1. The MLC 1 determines the true position of the mobile unit from the TOA receiver measurements, the reported repeater tag ID information, and a database 2 which includes geographical coordinates of the identified repeater.

It is understood that other embodiments of the present invention can be fabricated and be within the spirit and scope of the appended claims.

What is claimed is:

1. An RF data repeater system comprising:

a first diplexed antenna directed in the direction of a mobile unit;

a second diplexed antenna; and

a PN sequence generator electronically connected between the first diplexed antenna and the second diplexed antenna;

a data signal routed through the first diplexed antenna, the PN sequence generator and the second diplexed antenna; and

said PN sequence generator tagging said data signal with a non-interfering direct sequence spread spectrum signal.

2. The RF data repeater system of claim 1 further comprising a modulator electronically connected between the first diplexed antenna and the second diplexed antenna, and electronically connected to the PN sequence generator.

3. The RF data repeater system of claim 2 wherein said modulator performing phase modulation on said data signal.

4. The RF data repeater system of claim 2 wherein said modulator performing amplitude modulation on said data signal.

5. The RF data repeater system of claim 1 further comprising a filter/diplexer unit electronically connected to said first diplexed antenna, said filter/diplexer unit filters and separates the data signal according to its frequency.

6. The RF data repeater system of claim 1 further comprising at least one amplifier electronically connected to said first diplexed antenna to amplify the signal level of said data signal.

7. An RF data repeater system comprising:

a first diplexed antenna directed in the direction of a mobile unit;

a second diplexed antenna directed in the direction of a base station; and

a first PN sequence generator electronically connected between the first diplexed antenna and the second diplexed antenna;

a second PN sequence generator electronically connected between the second diplexed antenna and the first diplexed antenna;

an uplink data signal routed through the first diplexed antenna, the first PN sequence generator and the second diplexed antenna, said first PN sequence generator tagging said uplink data signal with a first non-interfering direct sequence spread spectrum signal; and

a downlink data signal routed through the second diplexed antenna, the second PN sequence generator and the first diplexed antenna, said second PN sequence generator tagging said downlink data signal with a second non-interfering direct sequence spread spectrum signal.

8. The RF data repeater system of claim 7 further comprising a first modulator electronically connected between the first diplexed antenna and the second diplexed antenna, and electronically connected to the first PN sequence generator.

9. The RF data repeater system of claim 8 wherein said first modulator performing phase modulation on said uplink data signal.

10. The RF data repeater system of claim 8 wherein said first modulator performing amplitude modulation on said uplink data signal.

11. The RF data repeater system of claim 7 further comprising a second modulator electronically connected between the second diplexed antenna and the first diplexed antenna, and electronically connected to the second PN sequence generator.

12. The RF data repeater system of claim 11 wherein said second modulator performing phase modulation on said downlink data signal.

13. The RF data repeater system of claim 11 wherein said second modulator performing amplitude modulation on said downlink data signal.

14. The RF data repeater system of claim 7 further comprising a filter/diplexer unit electronically connected to said first diplexed antenna, said filter/diplexer unit filters and separates the downlink data signal and uplink data signal according to its frequencies.

15. The RF data repeater system of claim 14 further comprising at least one amplifier electronically connected to said first diplexed antenna to amplify the signal level of said uplink data signal.

16. The RF data repeater system of claim 14 further comprising at least one amplifier electronically connected to said second diplexed antenna to amplify the signal level of said downlink data signal.

17. A position determination system comprising:

a) at least one data repeater, said data repeater further comprising

a first diplexed antenna;

a second diplexed antenna; and

a PN sequence generator electronically connected between the first diplexed antenna and the second diplexed antenna;

a data signal routed through the first diplexed antenna, the PN sequence generator and the second diplexed antenna; and

said PN sequence generator tagging said data signal with a non-interfering direct sequence spread spectrum signal tag;

b) at least one mobile unit;

c) a base station, said base station further comprising a location measurement unit for determining time of arrival of said data signal at the base station, said location measurement unit further comprises a PN code correlator for extracting said signal tag from said data signal;

d) a mobile location center for processing said time of arrival measurement and said signal tag into a position estimate of said mobile unit, said mobile location center further comprises a database which stores geographical coordinates of said repeater.

18. The position determination system of claim 17 wherein said position estimate is routed to an emergency response center.

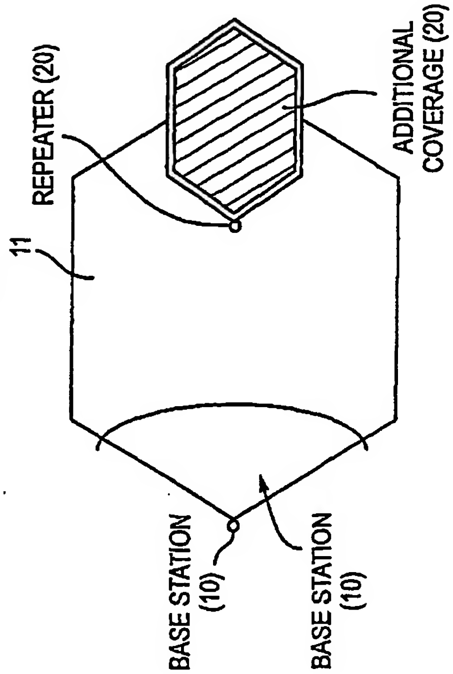
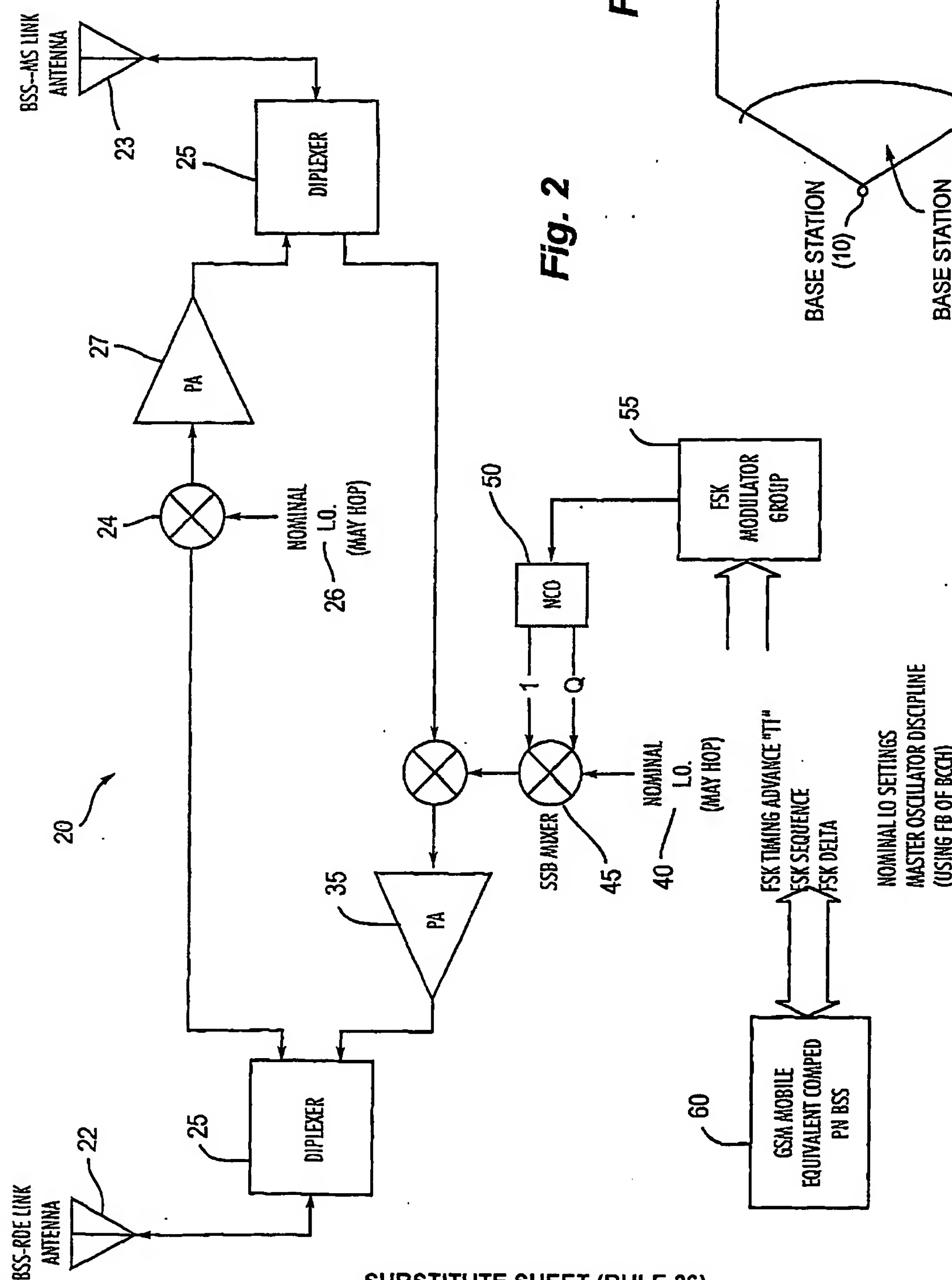

REPEATER (20)
ADDITIONAL COVERAGE (20)
11
BASE STATION (10)
BASE STATION (10)

Fig. 1


BSS--MS LINK ANTENNA
23
25
DIPLEXER
27
PA
24
NOMINAL L.O. (MAY HOP)
26
50
NCO
55
FSK MODULATOR GROUP
I
Q
20
35
PA
SSB MIXER
45
NOMINAL L.O. (MAY HOP)
40
FSK TIMING ADVANCE "TT"
FSK SEQUENCE
FSK DELTA
NOMINAL LO SETTINGS
MASTER OSCILLATOR DISCIPLINE
(USING FB OF BCCH)
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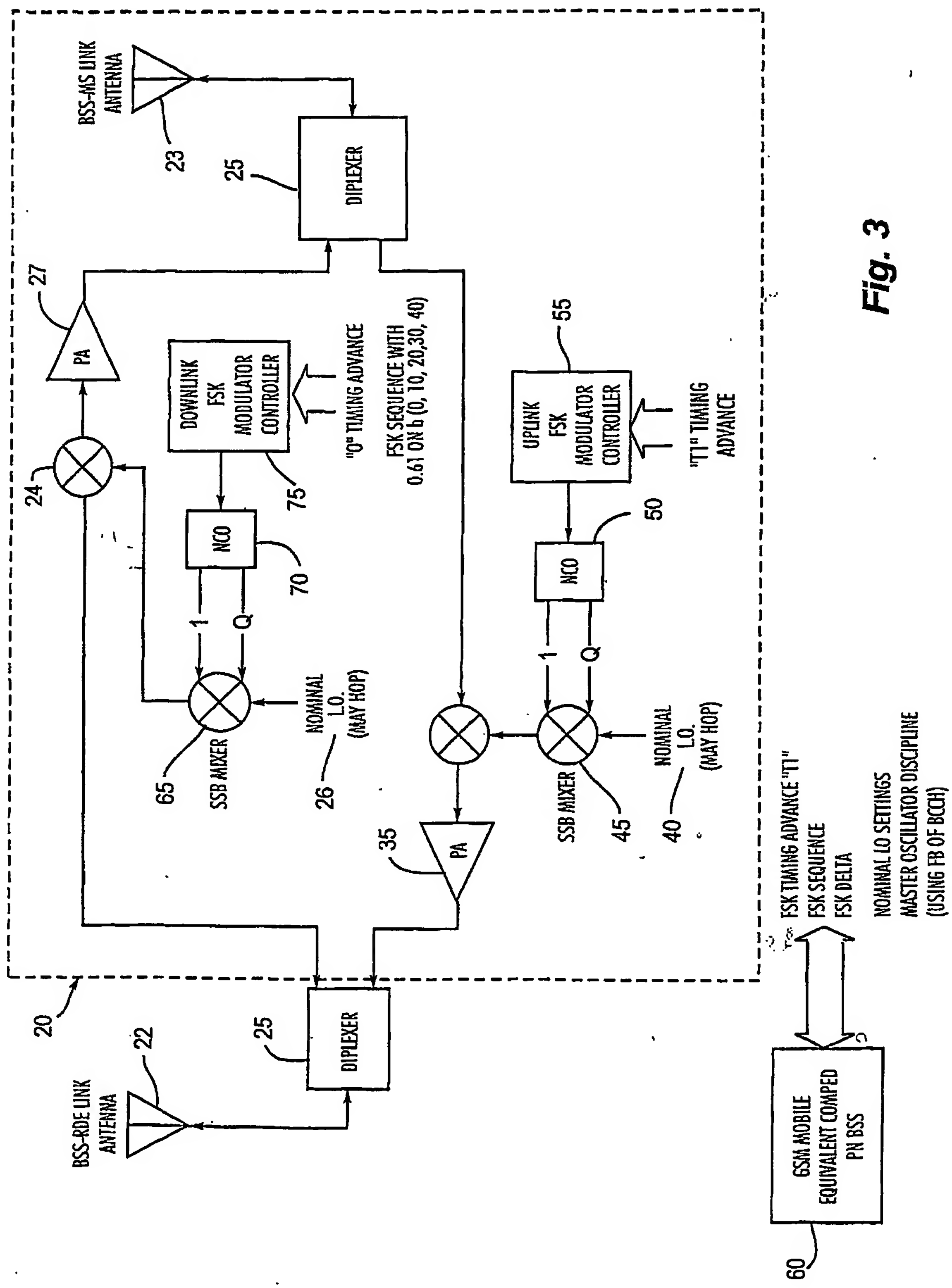
GSM MOBILE EQUIVALENT COMPED PN BSS
22
25
DIPLEXER
BSS-RDE LINK ANTENNA

Fig. 2


BSS-MS LINK ANTENNA
23
25
DIPLEXER
27
PA
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"0" TIMING ADVANCE
FSK SEQUENCE WITH 0.61 ON b (0, 10, 20,30, 40)
75
24
NCO
70
I
Q
SSB MIXER
65
NOMINAL L.O. (MAY HOP)
26
55
UPLINK FSK MODULATOR CONTROLLER
"T1" TIMING ADVANCE
50
NCO
I
Q
SSB MIXER
45
NOMINAL L.O. (MAY HOP)
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35
PA
20
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25
DIPLEXER
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Fig. 3

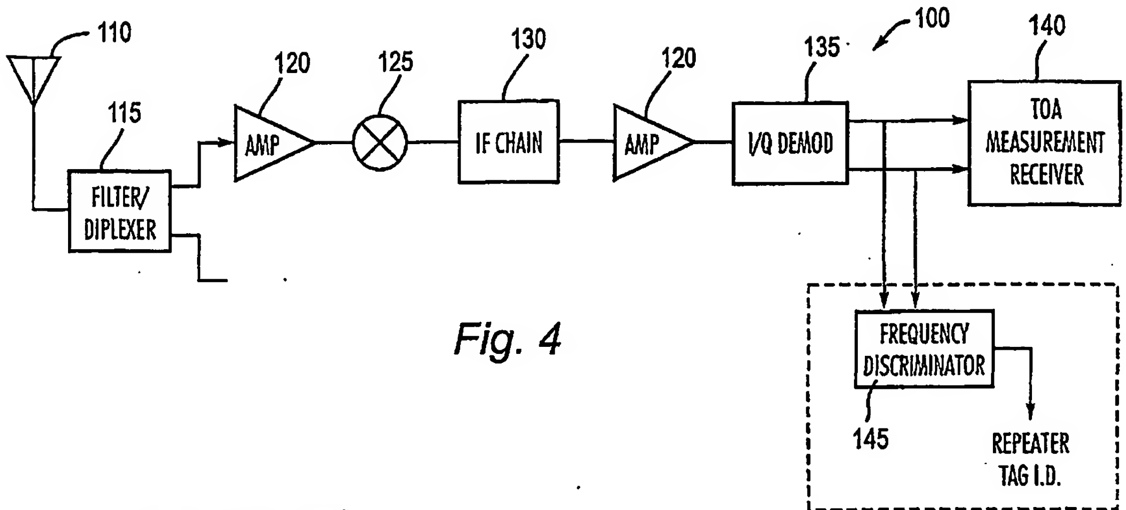

Fig. 4

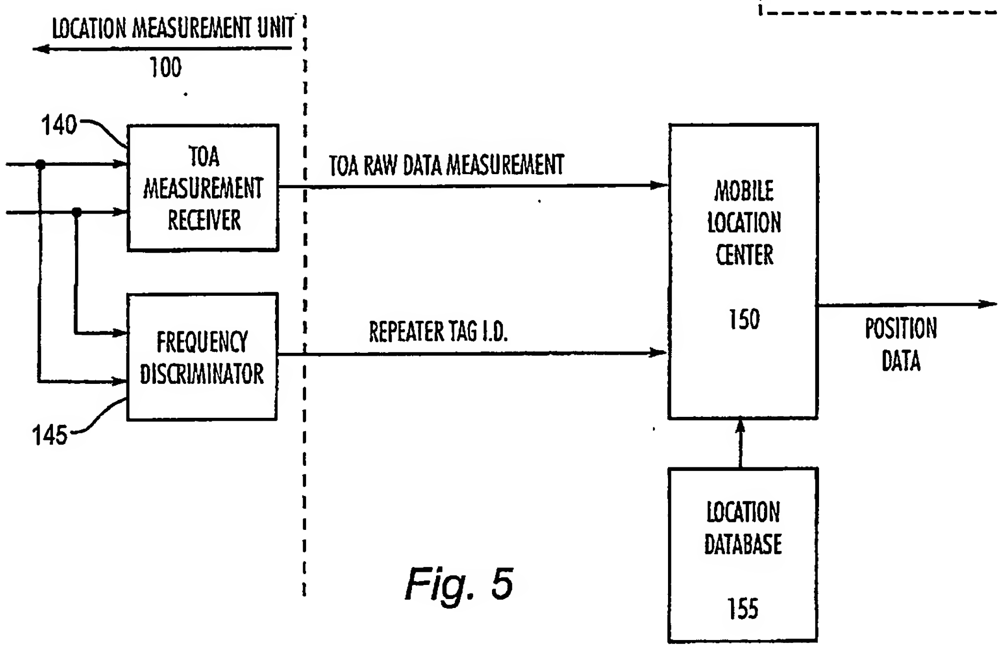

Fig. 5

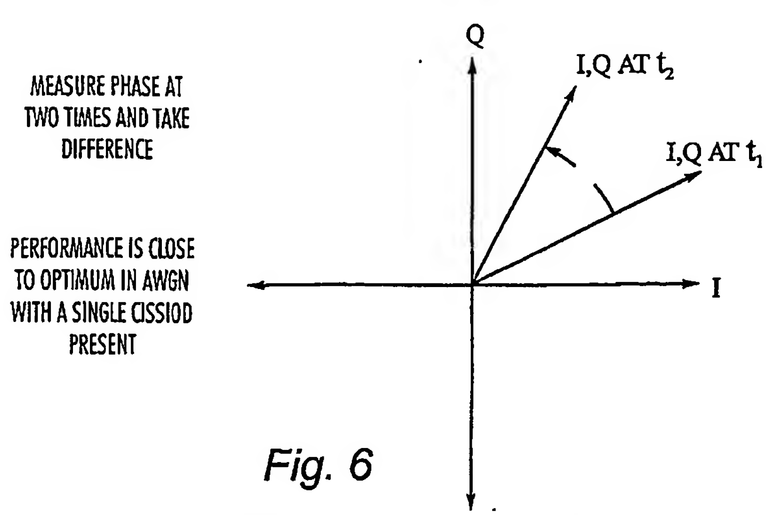

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/18379

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H04Q 7/20; G01S 3/02
US CL : 455/456, 7; 342/453; 375/134
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 455/456, 7, 11.1, 404, 521, 9, 10; 342/453, 457; 375/134, 137

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,978,650 A (FISCHER et al.) 02 November 1999 (02.11.1999), abstract, figures 1 and 2, column 1 line 58 - column 2 line 25, and column 5 line 6 - column 6 line 32.	1-18
A, P	US 6,108,364 A (WEAVER, JR. et al.) 22 August 2000 (22.08.2000), abstract	1-18
A	US 4,799,062 A (SANDERFORD, JR. et al.) 17 January 1989 (17.01.1989), see whole document	1-18

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 August 2001 (27.08.2001)	16 NOV 2001

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	PCT RAFAEL PEREZ-GUTIERREZ Telephone No. 703-308-8996

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US01/18379

Continuation of B. FIELDS SEARCHED Item 3:
WIPO Database (http://pctgazette.wipo.int)
EPO Database (http://ep.espacenet.com)
IEEE Xplore (http://ieeexplore.ieee.org/lpdocs/epic03)
EAST
search terms: repeater, booster, tag, signature, label, identifier, location, position, PN sequence, translator, address, header